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COST EFFECTIVENESS OF SOLE SOURCE CONTRACTING FOR NON-PERSONAL ENGINEERING SUPPORT OF FLIGHT SIMULATORS

FINAL REPORT

November 1980

Prepared under

Contract No. F33615-80-C-5173

for

AIR FORCE BUSINESS RESEARCH MANAGEMENT CENTER
Wright-Patterson AFB, Ohio 45433

Prepared by:

Bruce A. Dembroski
Paul Martin

Approved by:

Jacques S. Gansler
John Underwood

THE ANALYTIC SCIENCES CORPORATION
1700 North Moore Street
Suite 1220
Arlington, Virginia 22209

FOREWORD

This report examines the cost-effectiveness of single source versus competitive contracting for non-personal engineering support of flight simulators. The very determinant of this effort is the forecasting of savings which are produced by competitive procurement of those services. Numerous research undertakings have analyzed the effects of competitive weapon system procurement, and some studies have built a predictive framework for estimating savings due to competition. Few research efforts have attempted to quantify competitive procurement of service contracts. It is hoped that this analysis will help provide a foundation in this area.

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EXECUTIVE SUMMARY

The Analytic Sciences Corporation (TASC) has performed research and analysis to determine the potential savings from the competition of engineering support services for the Advanced Simulator for Pilot Training (ASPT). Engineering support is presently provided under three contracts by three different firms:

- Computer Image Generator (CIG) and Visual Display System -- General Electric
- Basic Cockpit Assemblies and Motion Systems -- Singer-Link
- General Purpose Computer System -- Systems Engineering Lab (SEL).

All three contractors have performed work on a sole source basis since 1975. The lack of adequate technical data packages for the General Electric and Singer contracts prevents the government from competing those services. The SEL technical data was adequate and competition was conducted for an FY 81-82 award of the support services for the General Purpose Computer System. This study provides estimates of the potential savings from competition of the present General Electric and Singer-Link service contracts.

The authors have developed an analytical framework, presented data which supports the framework, and used the framework for predicting competitive savings for the ASPT support services.

The framework applies cost improvement curve theory to service contracting. Unique features include:

- Definition of an "increment of progress" along the cost improvement curve's horizontal axis comparable to a unit of production
- Recognition of performance -- cost trade-offs by the contractor
- Analysis of the initial cost disadvantage of a competing second firm.

Application of the framework to service contracts produces estimates of potential savings from competitive procurement in a previously sole source situation. The competitive costs are predicted and then subtracted from the projected sole source costs, producing the potential savings estimates. These potential savings, if matched against the cost of a technical data package, when known, will determine the estimated net savings from competition for an initial five-year contract period. Additional savings will continue to accrue for subsequent periods.

Based on our analysis, specific application of the model to the ASPT contracts indicates:

- Potential savings due to competition for a five-year contract will be approximately \$1.4 million for the CIG and Visual Display System
- Potential savings due to competition for a five-year contract will be approximately \$600,000 for the Basic Cockpit Assemblies and Motion Systems.

These estimates represent potential savings of approximately 13 percent for the contract period, and do not include

the cost of a reprocurement data package. Additional cost savings may be realized if services for the CIG and Visual Display Systems and the Basic Cockpit Assemblies and Motion Systems are combined into a single support contract and competed. For this type of situation:

- Potential savings for the CIG and Visual Display Systems part of the contract for a five-year period will be approximately $2.9 million
- Potential savings for the Basic Cockpit Assemblies and Motion Systems part of the contract for a five-year period will be approximately $1.2 million.

These estimates represent potential savings of approximately 26 percent for the contract period, and do not include the cost of a reprocurement data package.

The research conducted to date indicates that applying cost improvement curve theory to many segments of the service industry could project, predict, and compare contract costs for a variety of contracting options. Additional research in this area may provide substantial insights into competitive contracting techniques for service type contracts.

1. INTRODUCTION

The Advanced Simulator for Pilot Training (ASPT) is an aircraft simulator which supports a program of experimentation and development for advanced flight simulator designs and concepts for use of simulators for flight training. The facility, located at Williams AFB, is operated and managed by the Flying Training Division of the Air Force Human Resources Laboratory (AFHRL), Air Force Systems Command.

When this one-of-a-kind simulator became operational in 1975, it could simulate only the T-37 aircraft. It supported Research and Development (R&D) programs which focused primarily on undergraduate pilot training. After undergoing a number of system modifications, the simulator now has the capability to simulate the T-37, A-10, or the F-16 aircraft. Also, further changes have increased capabilities for providing a combat tactics environment, an interactive combat scenario with another simulator, and support for specifically requested human factors studies. The ASPT currently provides a wide range of R&D support which includes the simulator System Program Office (SPO) and Tactical Air Command. Additional modifications are planned.

Engineering support services for the ASPT are currently provided by three contractors under three separate contracts:

Sub-System	Contractor
Computer Image Generator (CIG) and Visual Display System	General Electric

Sub-System	Contractor
Basic Cockpit Assemblies and Motion Systems	Singer-Link Division
General Purpose Computer System	System Engineering Laboratories (SEL)

These contractors not only provide regular maintenance and support services, but also make system refinements which occur on a continual basis.

The General Electric and Singer-Link contracts are cost-plus-fixed-fee (CPFF) while the SEL contract is firm fixed price (FFP). All the contracts were sole source through FY 198[illegible].

The main obstacle to competitive procurement of support services for the subsystems now supported by General Electric and Singer-Link is the lack of an adequate technical data package.

This study focuses on the cost benefits of competing the present G.E. and Singer-Link contracts. At the time that this report was prepared, the cost of reprocurement data packages was still unknown to the government. When firm bids are received from the contractors for the cost of technical data, or when the government is negotiating with the contractors for the package, these projected savings will provide an indication as to whether, or in what situations, it would pay to purchase the data. We have directed our efforts toward <u>predicting</u> the potential savings of a competitive situation for the ASPT services. The dollar size of the <u>potential</u> savings could provide an upper limit for the cost of a data package.

2. COST IMPROVEMENT CURVES

In analyzing the underlying theoretical concepts of competitive service contracting, TASC began its work with an examination of analytical tools previously used in competition studies. Principal among these were cost improvement or learning curves.

2.1 COST IMPROVEMENT CURVE THEORY

A cost improvement curve reflects the relationship between the unit cost (or unit price) of an item and the quantity of the item produced. An "80 percent" curve is one in which a doubling of output drives unit cost down to 80 percent of its initial value. That is, the cost of the 2Nth unit is 20 percent less than the cost of the Nth unit.

Simply stated, the cost improvement curve represents the decreasing costs of accomplishing any repetitive operation as the operation is continued. As any technically complex process is repeated, whether it is production of missiles or maintenance of flight simulators, employee and supervisory familiarity should grow, technical methods should improve, and managerial efficiency should increase.

2.1.1 Cost Improvement Curve in Standard Form

Graphically displayed in Figure 2.1-1 is a cost improvement curve in standard form. The curve shows the recurring cost of each unit of production as a function of total

quantity produced. The area under the curve is the total recurring cost of a given production run.

It is important to note the rapid cost improvement which is incurred early in the performance period. Each horizontal increment of progress yields a smaller absolute reduction in cost than the previous increment. As the curve grows increasingly flatter, larger amounts of production or work are required in order to further reduce cost until the cost improvement curve ceases to function as a useful tool. Producers and suppliers of relatively limited production quantities, or state-of-the-art engineering services (e.g., flight simulator maintenance), are rarely found on the flat end of the curve.

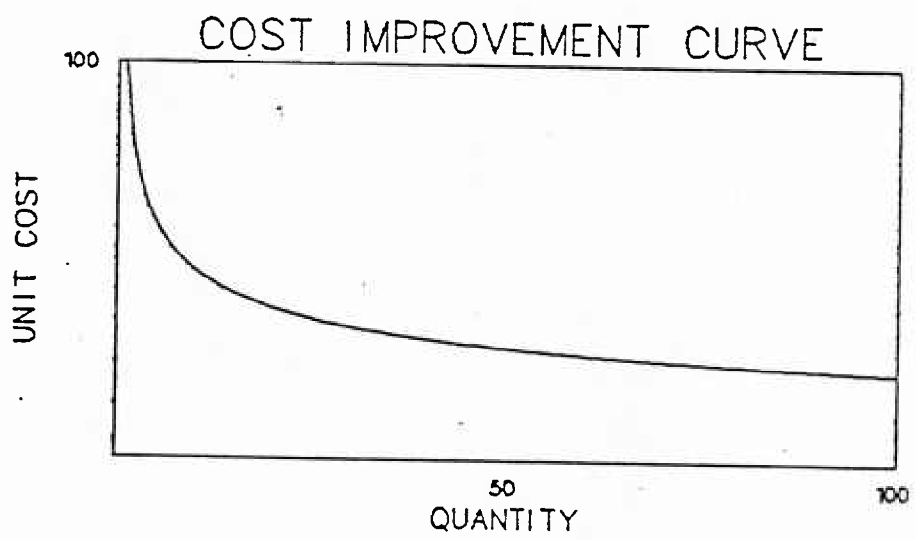

Figure 2.1-1 Cost Improvement Curve

2.1.2 Cost Improvement Curve in Logarithmic Form

It is possible to transform the standard cost improvement curve into logarithmic form. This is graphically displayed in Figure 2.1-2. Note that this transformation produces a linear relationship. It is important to remember that cost estimates are generated by the standard curve and that the area under the logarithmic curve is not a cost figure but a representation of total recurring costs.

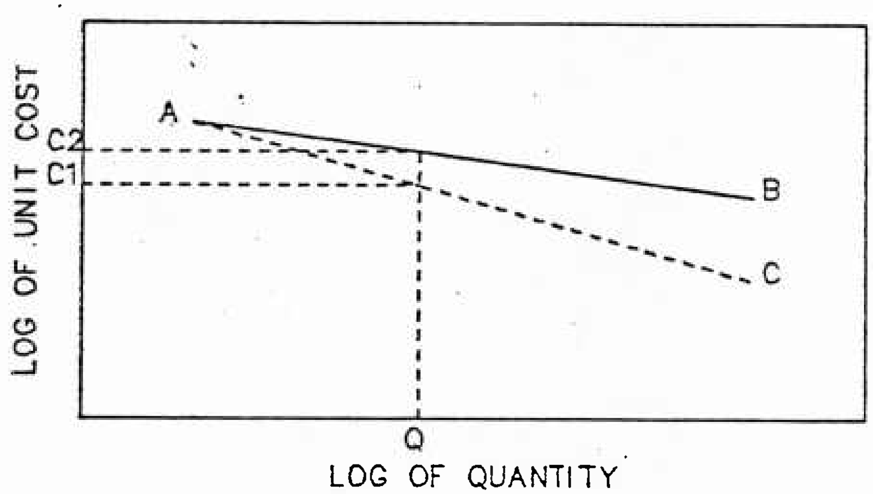

Figure 2.1-2 Cost Improvement Curve Displayed in Logarithmic Form

2.2 SERVICE COST IMPROVEMENT CURVES

Cost improvement curve analysis has been applied almost exclusively to production studies (e.g. missiles, aircraft, new consumer products) with little application to services. Lack of prior application to service areas probably arises from the difficulty of applying this type of analysis to service contracts, rather than from an inappropriateness of cost improvement curve theory. The theory fits service industry analysis, but requires modifications from production or hardware application.

Not all services, just as not all production situations, are subject to cost improvement curve analysis. As for production studies, the cost improvement curve effects for services are most notable for relatively new or complex situations. The cost improvement curve for custodial services, after a small and rapid period of cost improvement, is probably extremely flat. Most janitorial companies, or individuals, are well established on the flat part of the cost improvement curve. But for services where techniques used, skills required, and equipment serviced, are relatively new, complex, changing or diverse in nature, cost improvement analysis provides a useful analytical tool.

TASC has identified several major features of cost improvement curve theory which are applicable to service contracts. A discussion of those features follows.

2.2.1 Definition of an Increment of Progress

One immediate need for applying this type of analysis to service contracts is definition of an increment of progress along the cost improvement curve (i.e., a unit of production). Some period of performance is obviously the most convenient

way to measure quantity. The period of performance chosen should best reflect the repetitive nature of the work. With flight simulator maintenance, this choice is not easily identifiable. Although set daily routines exist, (training, repairs, data analysis, preventive maintenance, etc.), the same problems do not arise each day, indicating that the best incremental measure of progress is longer than a day.

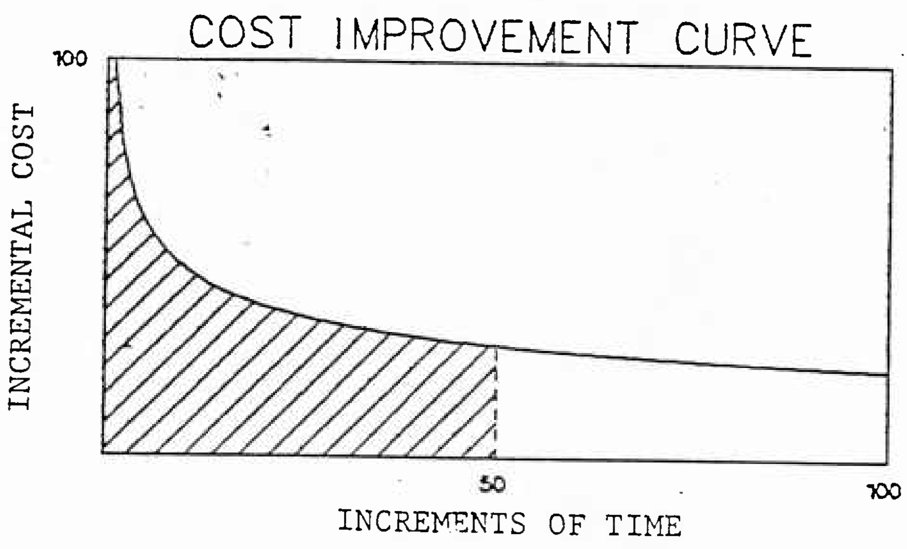

Figure 2.2-1 Service Cost Improvement Curves

To better define a suitable increment of progress for a flight simulator case, TASC has calculated sole source cost improvement curve rates using various increments of progress The results are presented in Table 2.2-1 and are based on contract data for the Simulator for Air-to-Air Combat (SAAC) at

Luke AFB. As the increments become smaller, the effect which they have upon the cost improvement rate becomes less significant. The sole source cost improvement rate varies little with increments of one month or less. Consequently, TASC selected one month as the increment of progress for analysis purposes.

TABLE 2.2-1
SAAC COST IMPROVEMENT CURVE RATES

Increment of Progress	Cost Improvement Curve Rate (Sole Source)
Fiscal Year	.84
Month	.895
Week	.902
Day	.904
Hour	.905

2.2.2 Level of Effort, the Cost Improvement Forces, and Contractor Performance

For many service contracts, a specified level of effort is required for the contract period. In these cases, the contractor is required to provide a certain number of manhours of service during the contract period. Cost improvement effects are not eliminated by this requirement, but simply emerge in a different manner.

With manpower levels fixed, employees will learn, technical skills will develop, and managerial efficiency will increase. These forces produce an improvement in contractor performance over the length of the contract. If manpower and

skills are allocated to meet performance standards at the beginning of the contract period and remain fixed throughout the contract, then the contractor performance levels will increasingly exceed government standards as time passes and as contractor experience grows. This has been observed for several contracts. The improved contractor performance represents the learning process within a contract period.*

The emergence of performance levels which exceed those required by the government indicates that the government can reduce specified manpower and skill levels and realize a cost reduction for the next contract. This reduction is graphically represented in the stairstep manner illustrated in Figure 2.2-2.

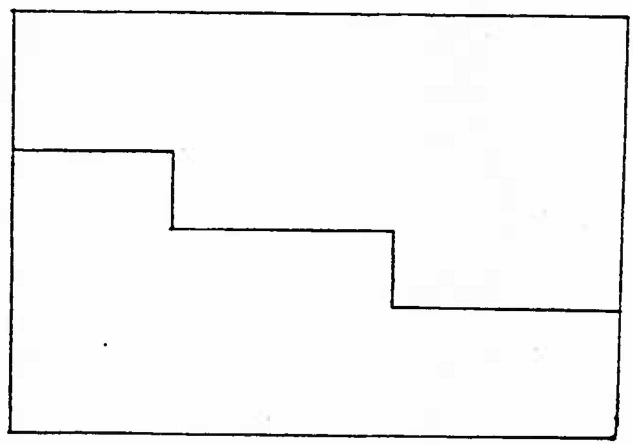

Figure 2.2-2 Level of Effort Reduction

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*This analysis assumes that employee idle time does not increase. If the increased efficiency and learning emerge as an increase in idle time, then performance levels will remain relatively stable.

During a contract period, the government will be unable to benefit from the cost improvement process in terms of reduced cost, but will receive an increase in performance beyond that required.

Cost improvement forces for level of effort contracts might emerge in a different manner than the performance improvement case described above. Assume a contractor is obligated to provide a specified number of manhours of service for the contract period, but is not required to allocate those manhours equally over all time periods. He may allocate his contractually required manpower and resources in a manner that reflects the actual cost improvement process. In this situation, relatively larger amounts of resources are used in providing service at the beginning of the contract period than are used in providing service near the end of the contract. Also, if the specified level of effort for a contract period is set too high, then where the contractor allocates his manpower and costs by following the actual cost improvement curve, performance will remain stable, but at a rate in excess of required government standards. The level of stairstep cost reduction between contracts is still driven by the underlying cost improvement forces. Figure 2.2-3 illustrates this point.

Performance tends to be more stable for this type of situation. The contractor will allocate his manpower or resources in a manner which produces a fairly constant level of performance.

In the health care field, one of the first service areas where TASC research revealed cost-improvement curve forces at work, the performance-cost-trade-off is easily identifiable. TASC's analysis of two Medicaid claims processing

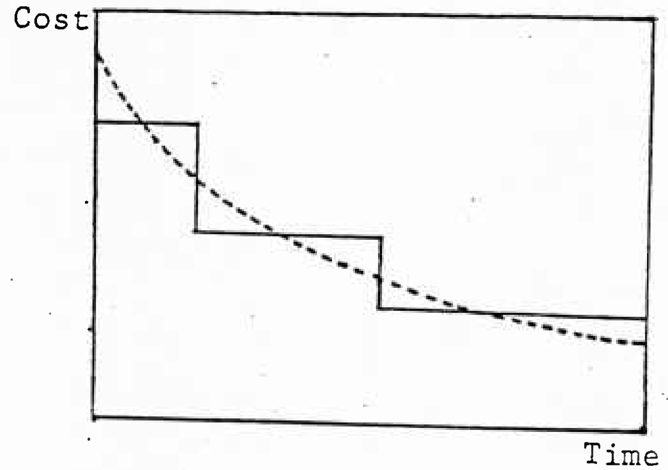

Figure 2.2-3 Cost Improvement Allocation of Manpower

contracts,* one sole source and one competitive, illustrates the trade-off. The cost per unit (claim processed) of the sole source contract showed no cost improvement present. However, contractor performance (error rate) exhibited a constant and clearly evident improvement to a level far in excess of government requirements. Cost per unit for the competitively bid contract followed a cost improvement curve and steadily declined over time. But performance levels in this case stayed essentially constant. (Chapter 3 continues a more extensive analysis of the effects of competition for service contracts.)

Two performance-cost situations for level of effort contracts have been discussed. The first, where the level of manpower resources is held constant during a contract period

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*Preliminary Performance Profiles of Contractors Operating Under Experimental Contracts, Health Care Financing Administration.

results in increasing performance levels. The second, where manpower follows a decreasing pattern with time, provides relatively stable performance levels. A combination of these two effects may occur. A contractor may allocate his manpower in a decreasing manner which does not entirely reflect all of the cost improvement forces. Performance levels will then increase, but at a slower pace than if resources were equally distributed over the entire contract period.

Table 2.2-2 illustrates a combination effect for the SAAC case. Even though the maintenance costs fit an approximate 90 percent cost improvement curve, the utilization rate for this system has steadily climbed to a level well in excess of the required 90 percent utilization rate.

TABLE 2.2-2
SAAC UTILIZATION RATE

FY	77	78	79	80
Rate	89.0	91.2	91.8	96.6

Many possible combinations of these two effects not only exist, but indicate the presence of performance-cost trade-offs by the contractor. The observation of a performance-cost trade-offs on cost improvement curves is unique to service contract analysis. In the production of hardware, a similar relationship may exist, but may require years before the quality or performance trade-off is known. With many service type contracts, the performance level is usually quickly and easily measurable and can serve as a useful tool in acquisition planning for follow-on contracts or changing current contracts.

2.3 ASPT COST IMPROVEMENT CURVE

Cost improvement curve analysis generally assumes that product design or scope of service remains unchanged. With this assumption, the cost improvement process is isolated and easily identifiable.

Unfortunately this type of static situation does not exist for the ASPT. The continual changes and modifications to the system have constantly redefined the scope of the work. For the ASPT, the cost improvement process may actually appear as in Figure 2.3-1. Each upward shift of the curve represents the increasing engineering maintenance costs which result from a system modification. After each shift, the cost improvement process continues, but at a higher level of costs.

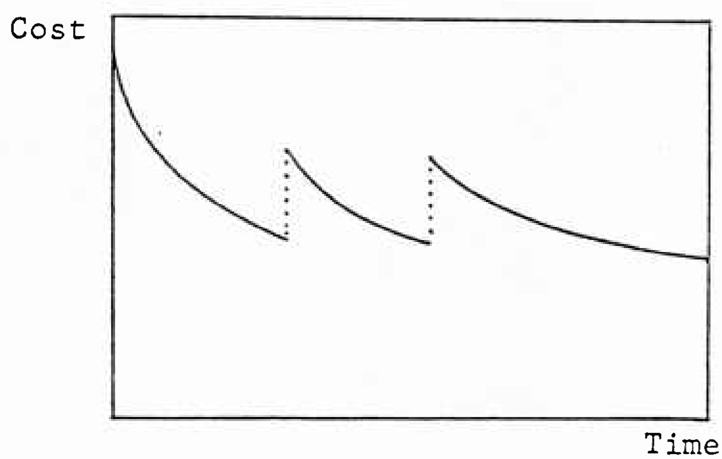

Figure 2.3-1 ASPT Cost Improvement Curve

Section 2.2 contains sole source cost improvement curve rates for the SAAC system. The sole source cost improvement curve rate for the ASPT, because of the many system modifications, is more difficult to determine. Using monthly

contractor reports and isolating a fairly static period for the ASPT, TASC has calculated cost improvement rates ranging between 90 and 95 percent. These rates, 90 percent for SAAC and 90 to 95 percent for ASPT, fall within the range of cost improvement rates for all sole source cases in the TASC data bank (see Table A-1, Appendix A).

TASC has collected and analyzed additional flight simulator maintenance and support data. This data is summarized in Table 2.3-1. The average sole source cost improvement rate for all flight simulators observed is approximately 90 percent. Therefore, we conclude that the calculated cost improvement rates for the SAAC and ASPT simulators are reasonable.

TABLE 2.3-1
SOLE SOURCE COST IMPROVEMENT CURVE RATES FOR FLIGHT SIMULATOR MAINTENANCE AND SUPPORT

F-4E/A-7D AAFTS	86.2
C-5/C-141	91.8
F-15	90.8
E-3A	95.3
F-111A-F	86.5
SAAC	89.5
ASPT	90.0 - 95.0
AVERAGE	90.0

2.4 CONCLUSIONS

TASC's analysis of cost improvement curves in relation to service contracts has produced the following conclusions:

- Cost improvement curve analysis is applicable to service type contracts. The forces which produce decreasing costs as any repetitive operation is continued, apply equally well to many service and production environments

- Distinguishing features of a service application include --

    Use of periods of time in place of units of production as the increment of progress along the horizontal axis of the cost improvement curve

    The existence of performance-cost trade-offs

- The ASPT cost improvement curve is continually shifting upward, representing the increasing cost of maintenance associated with system modifications and changes. The cost improvement curve rate, between shifts, approximates a 90 to 95 percent level.

3. EFFECTS OF COMPETITION

Chapter 2 dealt with sole source aspects of the cost improvement framework. Attention is now focused on the effects of competition on the cost improvement process, the relative cost position of the new competitor, and several aspects of a possible competition for ASPT service contracts.

3.1 BENEFITS OF COMPETITION

TASC has identified two distinct effects on the cost improvement curve due to the introduction of competition:

- A downward shift of the cost improvement curve (i.e., a reduction in costs and profits)
- A downward rotation of the cost improvement curve (i.e., a faster rate of improvement)

These two effects are graphically displayed in Figure 3.1-1. It is assumed that contracts were sole source up to point P_1, when competition takes place. The observed price reduction AP_2, due to competitive pressures, can be divided into three parts: AB, BC, and CP_2. The curve's parallel downward shift from A to B results from the reduction in profit; the area just above the dotted B line represents the total savings resulting from the firm's reduced profit. The reduction from B to C represents the cost reduction which the firm effected. It also is a parallel shift downward, with the area between B and C representing the total savings obtained by such

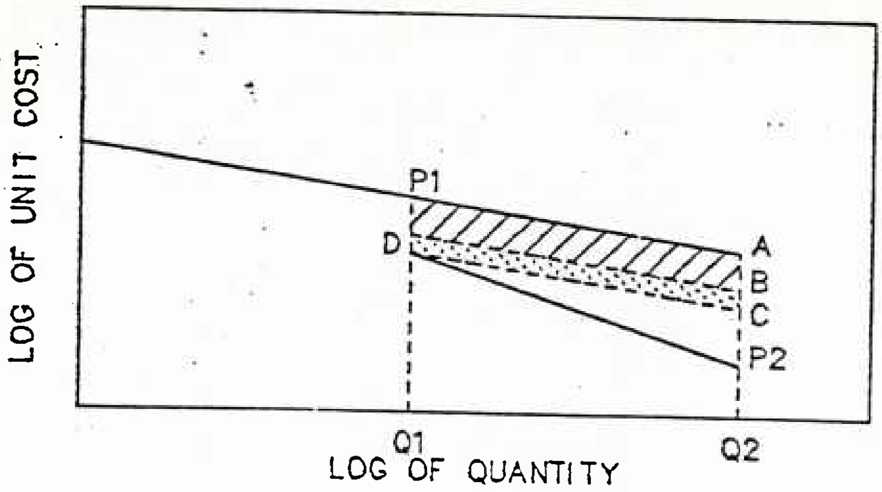

Figure 3.1-1 Benefits of Competition

cost reductions. The final reduction from C to P_2 represents a reduction based upon the firm's developing, under competition, a steeper cost improvement curve (i.e., a faster rate of cost improvement). The line DP_2 reflects the steeper slope.

Without the pressures of competition, the contractor would have continued along his projected sole source cost improvement curve, P_1 to A. The total area in $P_1AQ_2Q_1$ represents what the total costs would have been if the government had remained with a sole source producer. The area $DP_2Q_2Q_1$ represents the actual costs obtained under competition. The area P_1AP_2D represents the amount of potential savings due to competition.

It is important to recognize the cost of education resulting from an improved cost improvement rate represented by the area DCP_2. If such cost improvement changes are ignored, the entire change AP_2 is likely to be attributed to all future buys. However, it is clear in Figure 3.1-1 that the size of CP_2 critically depends upon the total number of periods for which service is provided. If the combined profit and cost savings due to competition can be established at a given level, (for instance, 15%), these savings can be retained for all

future periods of service. However, the gains from the downward rotation of the cost improvement curve (at point D) increase as the number of periods of service increase.

The potential advantage to the government for competing a previously single source procured service was illustrated by Figure 3.1-1. In that figure, the cost to the government of purchasing the service is easily identifiable and represented by the area under the cost improvement curve. Even if the new competitor wins the competition, the cost benefits to the government of competition are still present and represented by the shift and rotation of the cost improvement curve. Regardless of which competitor wins, the benefits of competition to the government emerge in the same fashion. Not only does an initial cost and profit reduction apply to all future periods of service affected by the competition, but also the cost improvement process occurs at an improved rate.

It is important to note these facts concerning Figure 3.1-1.

- The figure represents the cost to the government of initially purchasing a service by single source procurement and then competing future service contracts
- It represents the single source price schedule for providing the service to the government up to the point of competition. Since cost should move with price, except for the level of effort situation noted in Chapter 2, Figure 3.1-1 is indicative of the costs incurred by the single source firm*

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*This use of cost assumes that the fee received by the firm is simply a "cost" of keeping the firm in business.

- o If the second firm wins the competition, then Figure 3.1-1, after point P_1, does not represent the cost schedule of the new firm. Even though the price that the government pays can still be represented by the behavior depicted in Figure 3.1-, the actual cost curves of the second firm differs gratly from those curves depicted.

3.2 UNDERLYING COST TO THE SECOND FIRM

When faced with a competitive situation for a service previously procured from a single source, the second firm faces an underlying cost schedule as depicted in Figure 3.2-1.

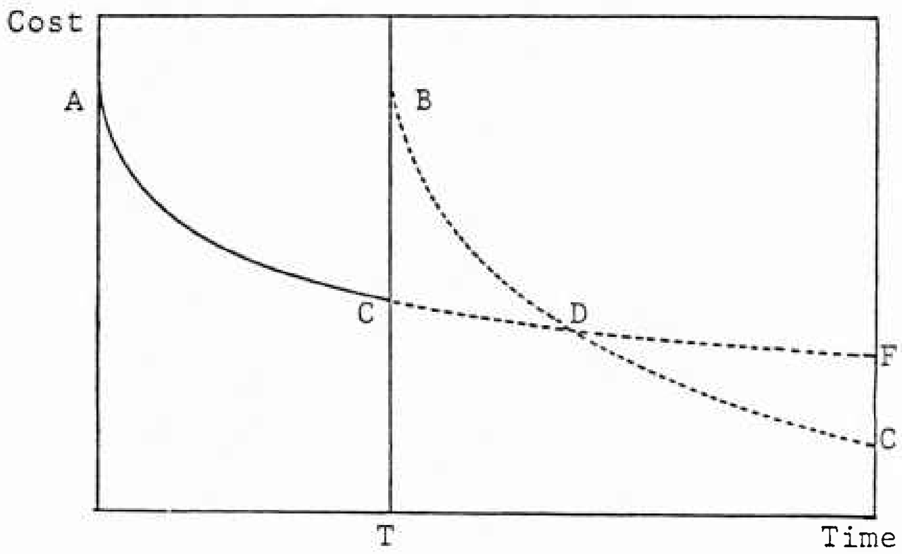

Figure 3.2-1 Underlying Cost to the Second Firm

Competition is conducted at time period T. Because of its lack of experience, the second firm must plan on beginning

service at some price B, which is in excess of the single source price C. If the second firm's cost improvement rate is steeper than that for the sole source firm, cost parity will be achieved at some point D. If, after reaching point D, the second firm were to move down the projected single source curve to point F, his total cost would exceed the projected single source total cost by the amount BCD. This is the experience cost for the second firm. If this was the basis of the second firm's bid, the single source firm would then win the competition by simply proposing a cost reflecting a move from point C to point F on its cost improvement curve. He would not feel any competitive pressure and would not have to reduce costs, profits, or improve his cost improvement curve rate to stay competitive (i.e., he would not have to shift and rotate his cost improvement curve).

The second firm, in an attempt to win the competition, must continue down a curve, after reaching point D, which is steeper than the projected single source curve, such as from D to G. The total amount of potential competitive savings over the projected single source cost in this case is equal to the area DFG minus the area BCD for the contract period.

The single source firm, in order to win the competition, must shift and rotate his original cost improvement curve by an amount that will produce a lower cost than what he estimates his competitor will bid. If the single source firm miscalculates and his bid does not reflect a large enough shift and rotation to overtake his competitor's proposed cost, the second firm will win the competition. In either event, the government benefits from the competition.

The recent competition for the ATC Instrument Flight Simulator (IFS) support service contract displays this kind of behavior. The support services for these simulators, which are located at various installations, were previously procured sole

source for approximately two-year periods under three separate contracts - Motion Base, Visual Systems, and Computer Image Generation. The three contracts were combined into a single contract and competitively bid for FY 1981 with a completely new competitor winning the competition. The cost data are presented in Table 3.2-1.

TABLE 3.2-1
IFS COMPETITION

	Non-Competitive FY80	Combined and Competitive FY81
Williams AFB		
Motion Base	\$35,600 per month	
Visual	\$40,833 per month	
CIG	\$ 8,200 per month	
TOTAL	\$84,633 per month	\$21,349 per month
Reece AFB		
Motion Base	\$35,374 per month	
Visual	\$45,911 per month	
CIG	\$ 6,150 per month	
TOTAL	\$87,435 per month	\$25,537 per month
Laughlin AFB		
Motion Base	\$35,517 per month	
Visual	\$44,902 per month	
CIG	\$ 7,200 per month	
TOTAL	\$87,619 per month	\$21,385 per month
Columbus AFB		
Motion Base	\$39,300 per month	
Visual	\$41,000 per month	
CIG	\$ 7,800 per month	
TOTAL	\$88,100 per month	\$21,229 per month

At first, the savings appear phenomenal and beyond what cost improvement curve theory could support. Discussions with individuals in the contracting office for these services provided some qualifying information. The contracting officer estimates that only 50% of the savings were a result of the competition, with the other half attributed to factors resulting from the economies of combining the three contracts into one contract.

Contract length is crucial to the results. In the IFS case, the winning contractor won a series of five, one-year options. Service for each option will be provided at the same real cost level. The dollar figures shown on Table 3.2-1 are the average monthly cost for the entire five-year period in FY 1981 dollars. With a five-year service horizon and an accelerated rate of cost improvement, the winning firm had ample time not only to achieve cost parity, but also to overcome the experience cost of achieving parity and produce a substantial savings to the government.

Although the government views the savings from the competition in terms of average monthly cost, with a firm-fixed price (FFP) contract and no specified level of effort, the winning firm will likely follow a cost improvement curve as depicted in Figure 3.2-2. Initially, actual costs would exceed the five-year monthly average. As the firm's experience grows, the cost improvement forces drive the actual monthly cost of service below the average monthly cost for the five-year period of performance.

The actual cost curve of the winning firm must also intersect the projected sole source cost improvement curve (as seen earlier in Figure 3.2-1). With the new competitor winning the IFS support contract and with the government realizing a

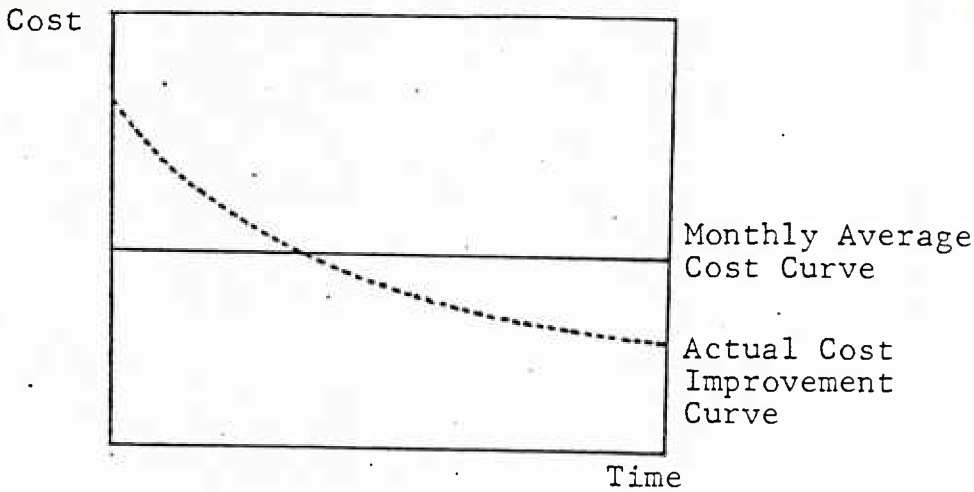

FIGURE 3.2-2 Actual Versus Average Cost

substantial savings from the competition, the point of intersection (or the cost-parity point) was apparently easily reached by the second firm. Two years of sole source experience by other firms presented little obstacle for the firm which won the competition.

The competitive savings from the IFS case easily fit into the developed analytical framework. With only one competitive contract point, the five-year monthly average cost, it is not possible to calculate a slope for the competitive part of the cost improvement curve. However, since the dollar amount of the savings is known, it is possible to calculate combinations of shift and rotations which produce the observed savings. Table 3.2-2 presents the results. By using any of the shift and rotation combinations listed in Table 3.2-2, the competition model would have accurately predicted the size of the IFS savings which were due to competition. For example, in order to remain competitive with the second firm's bid, the sole source contractors would have had to shift their cost improvement

curve downward by 12 percent and rotate the curve 16 percentage points. The observed competitive shifts and rotations due to competition on other previously sole source programs are presented in Table A-2 of Appendix A.

TABLE 3.2-2

RANGE OF IFS COMPETITION PARAMETERS

Shift	Rotation
8	20
10	18
12	16
14	15
16	13

Shift parameter is in percent; rotation parameter is in percentage points. Sole source cost improvement rate = 90%.

3.3 ASPT COMPETITION

Since the eventual effects of competition (i.e., a shift and rotation of the cost improvement curve) are strongly influenced by the experience cost of the second firm, careful analysis of specific factors which affect the second firm's cost improvement curve is required when determining parameters for the ASPT competition model.

Three factors help reduce the experience cost of the new competitors for a proposed ASPT competition.

- Immediate competitive pressure
- Performance-cost trade-offs
- System modifications.

3.3.1 Immediate Competitive Pressure

The second firm, unlike the sole source, would begin providing service at costs which were competitively bid and responsive to pressures of competition. The shift and rotation of his underlying cost schedule occur for his first period of service. Figure 3.3-1 below, which is similar but not identical to Figure 3.2-1, helps to illustrate this point.

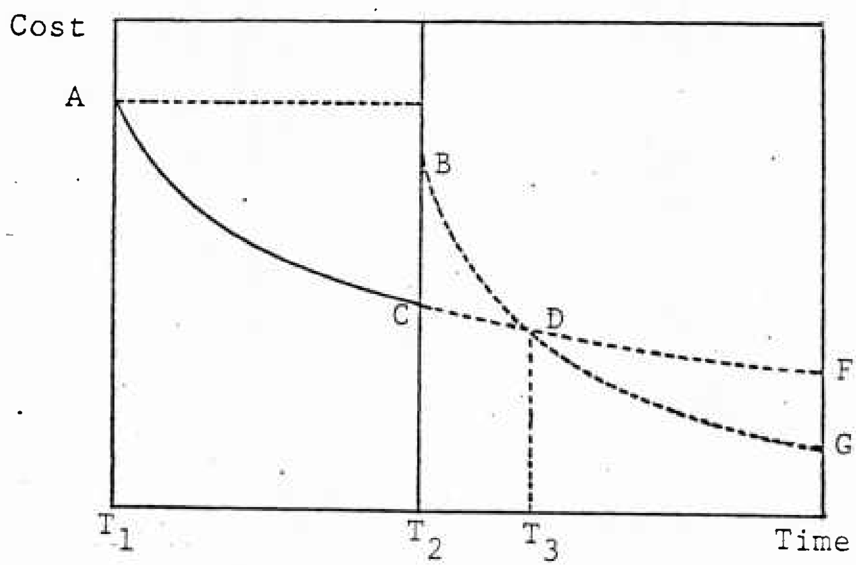

Figure 3.3-1 Immediate Competitive Pressure on the Second Firm

Figure 3.3-1 is drawn with point B, the cost of the second firm's initial period of service, lower than point A, the cost of the sole source contractor's initial period of service. Additionally, the second firm's cost improvement curve is more steeply sloped than the sole source curve with the intersection of the curves occuring at point D. Since the new firm is immediately faced with a competitive situation, he will logically begin, or bid to begin, providing service at a lower cost level and with a more rapid improvement rate than that which prevailed at the sole source determined point A.

If point B is placed at a cost level reflecting a 12% downward shift from point A, and if a 10 percentage point rotation is used for the second firm's cost improvement rate, then the period of time from T_2 to T_3 (the time required for the second firm to move from point B to point D) is equal to approximately 6% of the period of time from T_1 to T_3 (the time required for the sole source firm to move from point A to point D). Simply stated, with the above assumptions, the second firm requires only 6% of the service experience that the sole source contractor needed in arriving at the cost level represented at point D. For example, if the sole source firm has five years of sole source experience, the second firm would need only four months to obtain cost parity.

Although these numbers are only an example, they help illustrate the magnitude of the competitive pressures on the original sole source contractor. When shift and rotation parameters consistent with observed data on competitive procurements are applied to a new competitor's cost improvement curve at the initial period of service, the original contractor's cost advantage, projected by the sole source curve, is rapidly overcome.

3.3.2 Cost-performance Trade-off

As discussed in Chapter 2, when contract performance standards are steadily exceeded by substantial amounts, cost savings are made possible by employing less resources (or less costly resources) and lowering previous performance levels. This situation exists for the ASPT. The ASPT contractors' performance levels exceed the minimum standards set by the government. A new competitor can bid to provide ASPT support service at a reduced cost with lower resultant performance levels, but still meeting government performance standards.

For example, General Electric has steadily maintained a utilization rate for the CIG and Visual Display System substantially in excess of the required 90%. On recent monthly performance reports the utilization rate averages approximately 97% with several months displaying a 99% rate. A new competitor has sufficient room to reduce costs and still provide service at a level sufficient to meet performance requirements.

3.3.3 System Modifications

Finally, system modifications help to enhance the new firm's competitive position by partially under-cutting the cost advantage of the sole source contractor.

To understand how this process helps bring the second firm into cost parity with the single source, the cost improvement curve is viewed as a combination of smaller cost improvement curves. Equation 3.3-1 illustrates this point.

$$C_N = a_1 N^{b1} + a_2 (N-K)^{b2} \qquad (3.3\text{-}1)$$

Based on unit learning curve theory,

C_N = Cost of service in period N

a_1 = Cost of service in period 1

a_2 = Cost of service for modification in period K

K = Period in which system is modified

$b_1 = \frac{\log P_1}{\log 2}$ is the cost improvement rate for the original system

$b_2 = \frac{\log P_2}{\log 2}$ where P_2 is the cost improvement rate for the modification.

(The mathematical basis for the shift and rotation model is provided in Appendix B).

This equation shows that the cost of service in period N is the sum of two cost improvement curves. The first part, a_1N^{b1}, represents the cost of maintaining the original part of the system in period N. The second part, $a_2(N-K)^{b2}$, represents the cost of providing additional maintenance services which are a result of a system modification. If the modification has occurred recently, then (N-K) is relatively small, indicating that the single source firm has not moved very far down the modification cost improvement curve, thus increasing the opportunity for the second firm to achieve cost parity.

If the modification represents a major change to the system, then $a_2(N-K)^{b2}$ will make up a major portion of C_N, further aiding the second firm in gaining a competitive position. Theoretically, the cost improvement curves for each modification and the cost improvement curves for those parts of the original system which are still intact will sum to the total support cost for the entire system. If the modifications are recent, the sole source firm has not moved very far down the modification cost improvement curve and his cost advantage is reduced.

Although the effect of system modifications is difficult to measure based on available data, it is important to consider its possible impact when examining the original cost disadvantage of the second firm.

3.4 CONCLUSIONS

TASC's research and analysis of competition produces the following results:

- Competition produces two distinct effects on the cost improvement curve

  - A downward shift of the curve

  - A downward rotation of the curve

  The magnitude of these effects determine the amount of the potential savings due to competition

- A new competitor is faced with an underlying cost disadvantage because of the experience of the sole source firm. The new competitor must rapidly overcome this disadvantage or appear to the original source that he can if the government is to realize substantial savings from competition

- For the ASPT case, factors exist which help the second firm in obtaining cost-parity with the projected sole source case

  - Immediate competitive pressure on the second firm's cost schedule reduces his initial cost of providing service and hastens his rate of cost improvement over what would prevail in a sole source situation

  - A performance-cost trade-off allows the second firm to reduce his cost by providing service with lower performance levels than those provided by the sole source firm, but performance levels which still meet government requirements

  - System modifications result in a new cost improvement situation for both firms.

These factors not only help the second firm in achieving cost-parity with the sole source, they also allow the second firm to reduce his costs below the projected sole source costs, balance the experience cost of achieving cost-parity, and apply competitive pressure on the sole source firm.

The sole source contractor responds to the pressures of competition by shifting and rotating his cost improvement curve and reducing his proposed contract cost to the government.

4. ESTIMATING POTENTIAL SAVINGS

From the analytical framework that TASC has developed, it is possible to predict the approximate size of the potential savings which will result from competition for ASPT services. These potential savings, when matched against the cost of a data package, when known, will determine the net savings possible due to competition. The potential savings may also serve as a guide to the government during price negotiations for the data packages.

4.1 ASSUMPTIONS

Since a successful competition will produce a shift and rotation of the ASPT cost improvement curves, accurate parameter estimates are required for reliable savings forecasts. A number of other considerations which also affect the savings estimates include the cost of service at the time of competition, choice of an increment of progress, the experience cost which the second firm will face, and cost improvement curve slopes.

When determining the parameters which were used in predicting competitive ASPT savings, TASC examined the following:

- The IFS competition - where the cost improvement curve shift and rotation approximated 12% and 16 percentage points respectively
- The effect of competitive pressure on the second firm's experience cost

- Performance - cost trade-offs
- Aspects of the General Purpose Computer System Competition
- Number, extent, and timing of the ASPT modifications
- Monthly data reports for the ASPT.

Based on the analysis of these considerations, the developed framework, and available data, the following were used for estimating potential savings:

- Monthly support cost for the Computer Image Generator and Visual Display System just prior to competition is $230,000 (FY83 dollars)
- Monthly support cost for the Basic Cockpit Assemblies and Motion Systems just prior to competition is $97,470 (FY83 dollars)
- Competition is conducted for a FY 83 award
- A month is used as the increment of progress
- Sole source cost improvement curve rates are 90%
- The shift parameter is set at 12%
- The rotation parameter is set at a conservative 5 percentage points.

The monthly support costs were calculated by reviewing G.E. and Singer costs for an FY83 extension to their current contracts, which is the earliest possible time the government can conduct a competition. Based on contractor functions, the nature of the service, and data analyses, a month was considered the most appropriate increment of progress. The 90% sole source cost improvement curve rate was the average of all flight simulator contracts examined. The values chosen for the shift and rotation

parameters were based upon observations of other competitive situations which suggest that those values are probably conservative.

4.2 RESULTS

Using its computer based competition model, TASC has calculated the results shown in Table 4.2-1. This application assumes prices are in constant FY81 dollars and produces potential savings for various contract lengths. If the competition is conducted for a five-year contract as opposed to a two-year contract, the size of the potential savings due to competition increase. As contract length increases, the additional savings realized will also increase. The downward rotation of the cost improvement rate produces increasing marginal or incremental savings for each additional year.

TABLE 4.2-1
POTENTIAL SAVINGS FROM COMPETITION
(FY81 dollars)

Contract Length	2yrs.	3yrs.	4yrs.	5yrs.
CIG and Visual Display System	564,000	861,000	1,167,000	1,479,000
Basic Cockpit Ass. and Motion Systems	239,000	365,000	495,000	628,000

These numbers represent conservative savings estimates of between 12% and 13% for ASPT engineering support services. These estimates are dependent on the stated assumptions. If new information or events substantially change any of the assumptions, then the above estimates will change accordingly.

For example, if additional system development increases future maintenance requirements above the expected levels, then the expected savings from competition should also increase.

The estimates listed above indicate approximate prices below which the cost of a data package must fall in order to produce positive net savings. For example, if General Electric requires \$5 million to develop a data package, then for the conditions analyzed it would not pay the government to compete. On the other hand, if the data package cost for this part of the system was \$1 million, competition would produce a substantial net savings for a five year service contract.

These potential savings are best achieved, as in the IFS competition, under a firm fixed price (FFP) contract with a specified level of performance rather than a specified level of effort. This type of contractual arrangement leaves the contractor free to realize the cost improvement process, where he provides acceptable performance at decreasing costs, and where the government realizes the cost savings.

At the end of the competitive contract period, the contractor will have attained a position on his cost improvement curve which is substantially below the projected sole source curve. This position should affect the costs of the next contract. (This assumes that the flat end of the cost improvement curve has not yet been reached. With the several modifications which are planned for the ASPT in the next few years, this is not an unrealistic assumption). For example, assume that the government competes the CIG and Visual Display System and realizes a substantial net savings from a five-year competitively bid contract. After the contract expires, the government decides that it is not cost effective to compete the next contract (i.e. additional technical data is too expensive, experience cost of second firm is now too high, etc.). Costs of the next

contract, even though the contract is not competitively bid, should not revert back to the single source cost improvement curve, but should remain at least partially affected by the previous competitive experience. Without data on distant future costs, modifications, and technical requirements, estimation of this continuation effect is unreliable. However, for a borderline competition decision, where the cost of the technical data approximately equals potential savings, knowledge of the existence of this effect may indicate that the government should compete.

4.3 COMBINATION OF THE CONTRACTOR SERVICES

The purchase of a technical data package by the government offers an additional cost saving benefit, aside from competitive savings, which helps in recovering the initial cost of the data. Technical data not only makes competition possible, but allows consolidation of multiple contracts into one contract, thus producing additional benefits due to economies of scale. Together, competition and a single contract help recover the purchase price of the technical data.

TASC has analyzed the IFS competition, where both effects were present, and has found two primary components for economy of scale savings from the combination of the contracts.

- Reduction in the managerial and supervisory staff positions
- Cross utilization of employees.

These savings, when fit into our developed framework, represent a downward shift in the cost improvement curve. They represent a permanent cost reduction which will apply to all future periods of service. For the IFS case, the shift parameter for this economy of scale effect was approximately 37%, more

than twice what was expected by government contracting personnel. If a competitive shift of 12% is added to this 37% figure, a total cost improvement curve shift of 49% is observed.

It is possible to estimate the total potential savings (competition plus economics of scale) for the ASPT. Assume a situation where General Electric not only bids on the CIG and Visual Display System, but also competes for Singer's contract on the Basic Cockpit Assemblies and Motion Systems. Also, assume the opposite, where Singer bids not only on its usual service, but attempts to win the G.E. service contract. Based on our analysis, these situations will produce larger potential savings from competition than those presented in Table 4.2-1 for two reasons. First, a larger shift of the cost improvement curve will occur because of the combination of the contracts. Second, each competitor is at least somewhat familiar with the other's system. The initial experience cost for providing service on another part of the ASPT is not as great for General Electric or Singer as it is for a completely new competitor.

Table 4.3-1 provides potential savings estimates for the G.E.-Singer competition for a five-year contract. Except for the shift and rotation parameters, all of the earlier assumptions apply to this case. The shift parameter, now reflecting the total of the competition and economy of side effects, increased to a conservative 24%. (The results of IFS competition and government contracting personnel estimates indicate that a total shift of between 27 and 49 percent is more appropriate.) The previous rotation parameter of 5 percentage points was changed to a more reasonable 10 points to reflect the system familiarity of the two contractors. An additional assumption is that one contractor wins both contracts or performs both functions on a single contract. Table 4.3-1 contains the estimated five-year savings which represent 26% of the expected sole source costs.

TABLE 4.3-1

Potential Savings from a GE-Singer Competition

	5-year Savings (FY 81 Dollars)
CIG and Visual Display System	$2,915,000
Basic Cockpit Ass. and Motion Systems	$1,235,000

The General Purpose Computer System (GPCS) was not included in the combination of contract analysis. Since no technical data cost is required to include the GPCS and in an attempt to remain conservative, potential savings from that portion of the ASPT were excluded from the analysis.

In summary, the combination of contractor services into one contract, through the additional benefits from economics of scale and increased competitive pressure, improves the amount of potential savings which the government may realize from competition. With TASC utilizing a conservative approach for the potential savings calculations, these estimates represent a realistic maximum cost limit which the government can safely expect to amortize through competitive and economy of scale savings.

5. SUMMARY AND CONCLUSIONS

The authors have developed an analytical framework, presented data in support of the framework, and forecasted potential savings based upon the stated assumptions. The framework, which applies cost improvement curve theory to service contracts, is based upon a competitively induced shift and rotation of the cost improvement curve. This framework was used by the authors for predicting future support costs and potential savings due to competing support services for the Advanced Simulator for Pilot Training (ASPT).

Few government officials actively use the cost improvement process to project future costs when negotiating service contracts. When contracting officers recognize an improvement in contractor performance during the most recent contract period, they will redefine the scope of the required work for the next contract. The excess manpower, resources, and skills must first be observed, and then the cost reduction is effected on the next contract. This type of passive use of the cost improvement process delays any possible cost reduction by at least one contract period. TASC's analysis actively uses the cost improvement process for projecting future costs and assessing contracting options based on these projections. This application of cost improvement theory, also allows a comparison of projected sole source and predicted costs due to competition.

Major features of the authors' application include:

- Increments of progress along the cost improvement curves' horizontal axis

- Performance - cost trade-offs
- Initial cost disadvantage to the second firm.

Data analysis supports the TASC shift and rotation theory and provides evidence of the applicability of cost improvement curve theory to service contracts. Service cost improvement curve rates are presented and the theory is applied to a previous flight simulator competition.

Application of the framework predicts that competition may recover the following approximate costs for a technical data package. These numbers represent an approximate 13% potential savings.

CIG and Visual Display Systems	$1,479,000
Basic Cockpit Assemblies and Motion Systems	$ 628,000

These numbers are based on five-year FFP contracts, where contractor manpower is not held to a specified level of effort.

When a competitive situation exists with General Electric and Singer as competitors for a combined service contract, the potential savings estimates are increased. The potential savings estimates represent an approximate 26% potential savings.

CIG and Visual Display Systems	$2,915,000
Basic Cockpit Assemblies and Motion Systems	$1,235,000

These estimates provide reasonable limits on what price the government can afford to pay for a technical data package.

This study should represent the first of many research efforts into the costs and benefits of competitive service contracting. Aside from a need for additional research into the cost factors which affect service contracts, more data is needed for both the general service area and specific service industry segments.

Specific areas of data collection and research to develop a predictive framework and model for service type contracts would include:

- Determine the presence and magnitude of cost improvement rates for specific segments of the service industry. Typical segments not only include engineering support services, but also cover operations and maintenance and custodial type services
- Determine the presence and magnitude of cost improvement curve shifts and rotations in the presence of competition for each industry segment
- Assess the potential impact of contract type (CPFF, FPIF, etc) and other contract features on the cost improvement rate, shift and rotation for both sole source and competitive contracts for services for each industry segment
- Assess the effects economy of scale have on cost improvement rate, shift and rotation for each service industry segment
- Assess the effects of requirements added during the contract period on cost improvement rate, shift and rotation for each service industry segment.

The results of this analytical research would increase the sensitivity of acquisition personnel and resource planners to cost improvement curve effects on competitive and sole-source service contracts. Thus, it would improve their ability to anticipate, recognize and stimulate cost improvements by contractors and improve the government's negotiating position for non-personal service contracts.

TABLE A-1

SOLE SOURCE LEARNING RATE FOR VARIOUS PROGRAMS

TOW LAUNCHER	93.0%
FAAR RADAR	88.0%
FAAR TADDS	88.0%
AN/ARC-131 RADIO	99.0%
UPM-98 TEST SET	85.0%
PP 4763/GRC POWER SUPPLY	95.0%
HAWK MOTOR METAL PARTS	87.4%
TD-204 CABLE COMBINER	86.6%
TD-202 RADIO COMBINER	82.8%
TD-352 MULTIPLEXER	95.8%
TD-660 MULTIPLEXER	70.8%
60-6402 ELECTRIC CONTROL	95.7%
MK-48 TORPEDO - WARHEAD	88.8%
MK-48 TORPEDO ELECTRIC ASSEMBLY	80.6%
SPA-66 RADAR INDICATOR	95.4%
ROCKEYE BOMB	82.0%
APX-72 AIRBORNE TRANSPONDER	80.5%
AN-ARC-54	92.4%
AN-PRC-77 RADIO	85.6%
AN/GRC-106	84.0%
AN/GRC-103	90.4%
AN/APM-123	96.9%
SPA-25 RADAR INDICATOR	72.7%
USM-181 TELEPHONE TEST SET	82.1%
FGC-20 TELETYPE SET	97.0%
MD-522 MODULATOR DEMODULATOR	85.9%
750 BOMB, M117	90.0%
CV-1548 SIGNAL CONVERTER	82.7%
SIDEWINDER AIM-9D/G	92.0%
SIDEWINDER AIM-9B	83.0%
SPARROW 7F	87.0%
HARPOON	92.0%
TALOS MISSILE	93.3%
BULLPUP 12B MISSILE	81.0%
AVERAGE FOR 34 PROGRAMS	88%

TABLE A-2

LEARNING CURVE SHIFTS AND ROTATIONS - MULTIPLE SOURCE
(SELECTED PROGRAMS)

PROGRAM	CONTRACTOR	SHIFT (IN PERCENT)	ROTATION (PERCENTAGE POINTS)
SPARROW 7F	(RAYTHEON)	7	9
	(GENERAL DYNAMICS)	11	16
BULLPUP	(MARTIN)	19	7
SIDEWINDER-9B	(GENERAL ELECTRIC)	9	14
750 BOMB, M117	(LETOURNEAU)	17	7
SHILLELAGH	(PHILCO-FORD)	12	5
	AVERAGE	12.5	11.0

APPENDIX B
MATHEMATICAL MODEL

The TASC model for analyzing the effects of competition in production is based on unit learning curve theory and an observed phenomenon based on extensive research that learning curves are altered when competition is introduced. This phenomenon is characterized by a shift and a rotation in the learning curve when plotted in log-log form (Figure B-1).

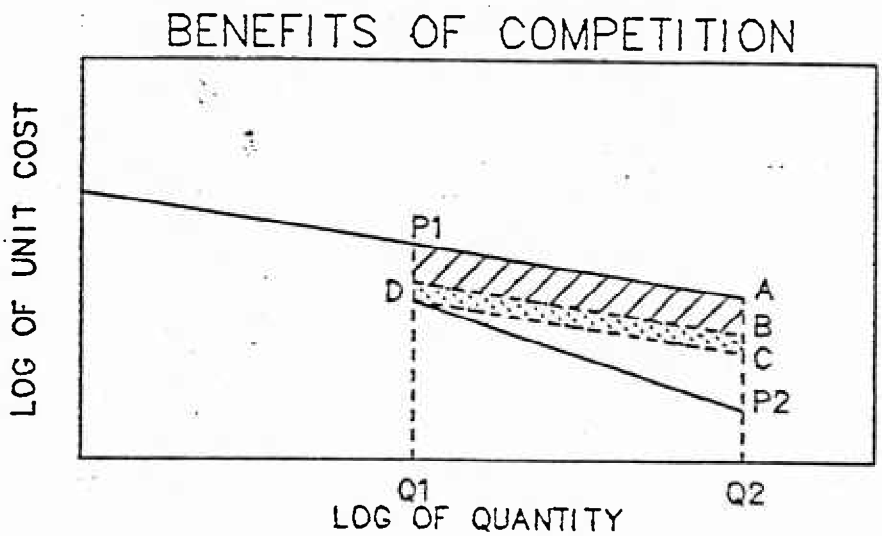

Figure B-1 Benefits of Competition

Figure B-1 assumes that service was single source to Q1. At that point, competition with another firm was introduced. If we assume that the original firm won a competitive buy-out, the figure shows that the firm's price P1, fell to P2 at the end of the competition. Since the firm would have progressed along its learning curve to point A, the distance AP2 represents the gross savings due to competition.

The price reduction AP_2 can be divided into three parts: AB, BC, and CP_2. The curve's parallel downward shift from A to B results from the reduction in profit; the area just above the dotted B line represents the total savings resulting from the firm's reduced profit. The reduction from B to C represents the cost reduction which the firm effected, with the area between B and C representing the total savings obtained by such cost reductions. These two downward shifts are combined to represent the shift in cost due to competition. The final reduction from C to P_2 represents a reduction based upon the firm's developing, under competition, a steeper learning curve (i.e., a faster rate of learning). The line DP_2 reflects the steeper slope and the area in triangle DCP_2 represents the total savings as a result of increased learning. The total area in $P_1AQ_2Q_1$ represents what the total costs would have been if production remained single source. The area $DP_2Q_2Q_1$ represents the actual costs obtained under competition.

The TASC competition model estimates single source and competitive costs based on unit earning curve theory. This can be mathematically expressed as follows. The cost of the K^{th} unit, C_k, in unit learning curve theory is:

$$C_k = A_1 K^B$$

where

$$B = \frac{\log P}{\log 2}$$

P = the learning curve rate

A_1 = the cost of the first unit

Note: If A, is unknown, but some Aj is known for unit j, A_1 can be calculated by $A_1 = Aj/j^B$.

The total cost of K units following completion of N units is as follows:

$$C_N^K = A_1 \sum_{i=N+1}^{N+K} i^B$$

In order to simplify computation, the TASC model uses the following equation:

$$C_N^K = A_1 \int_{N+0.5}^{N+K+0.5} x^B dx$$

then

$$C_N^K = \frac{A_1}{B+1}\left[(N+K+0.5)^{B+1} - (N+0.5)^{B+1}\right]$$

The effects of competition on B and A are calculated as follows:

$$B^1 = \frac{\log p^1}{\log 2}$$

where

$$p^1 = p(1\text{-}ROT)$$

$100 \times ROT$ = percent rotation of learning curve rate

$$A^1 = A_1(1\text{-}SFT)N^{(B-B^1)}$$

where

N = number of service periods (units) prior to competition

$100 \times SFT$ = percent reduction (a shift) in cost

Thus the cost of K periods following service for N units where competition occurs after the N^{th} period is produced is as follows:

$$C_N^K = \frac{A^1}{B^1+1}\left[(N+K+0.5)^{B^1+1} - (N+0.5)^{B^1+1}\right]$$

The incremental costs are included by adding their values to the total service costs of the contracts.

The computer simulation of the competition model uses the above theory to compare single source to competitive costs. Model outputs include:

- Yearly contract costs
- Total costs (including incremental costs)
- Savings

The model requires the following inputs:

- Service schedules
- Incremental cost and increment number
- Learning curve slope
- Learning curve shift
- Learning curve rotation

- Decision lot size
- Performance start year
- Competition start year
- Incremental dual source costs
- Inflation and discount rates.

The model also offers several options to perform sensitivity analysis on the input parameters. The following inputs can be examined:

- Decision lot size
- Learning curve shift
- Learning curve rotation
- Learning curve rates
- Unit costs.